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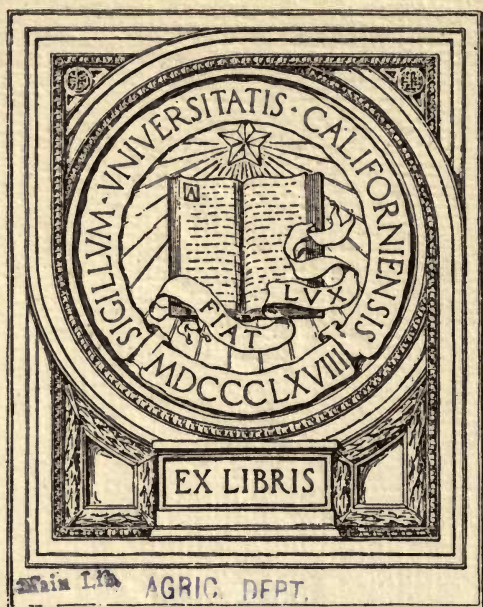
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U. S. D. A. INVESTIGATIONS ON NUTRITION
OF MAN IN THE UNITED STATES. 1904

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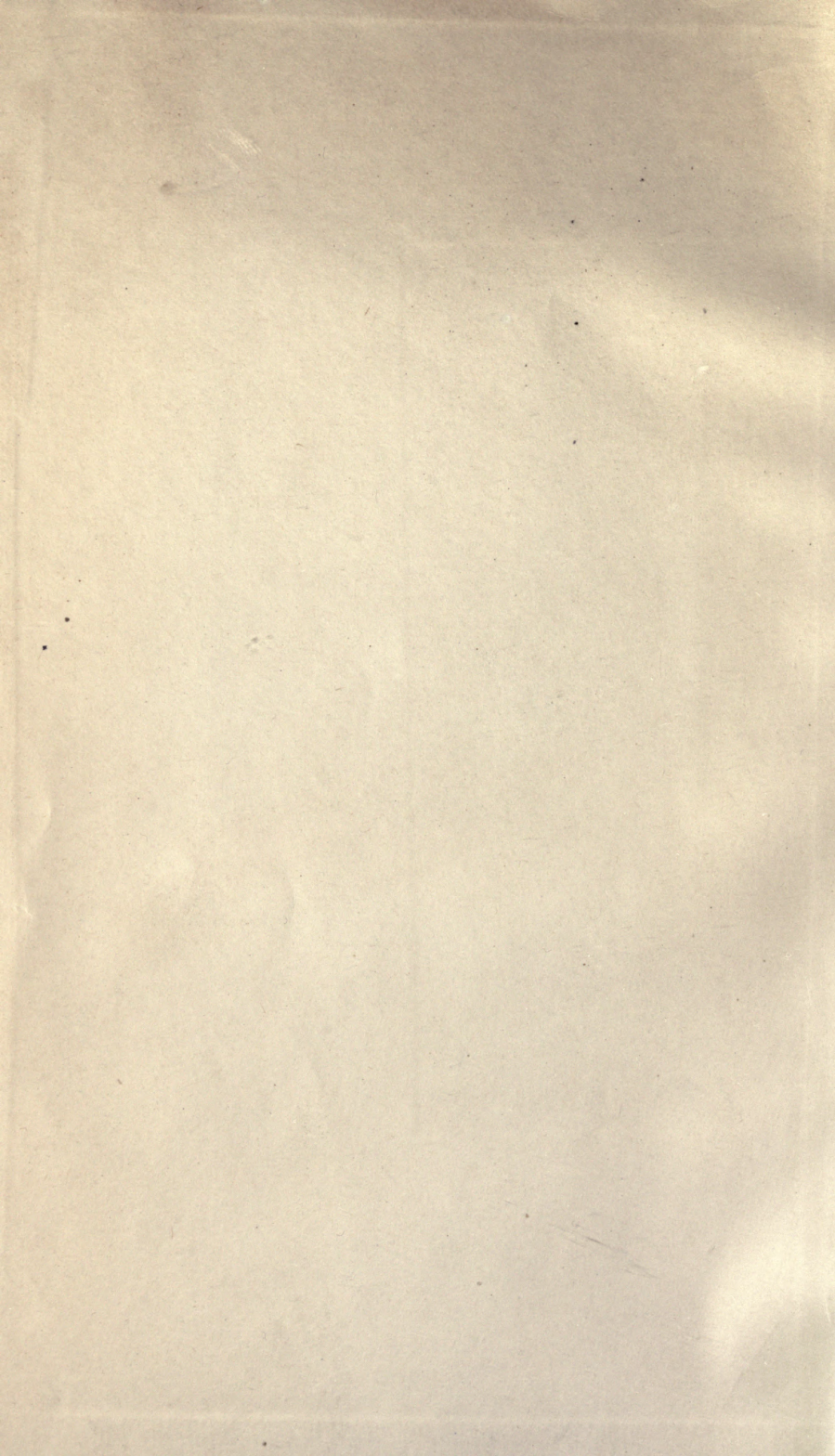
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A. C. TRUE, Director.



INVESTIGATIONS
ON THE
NUTRITION OF MAN
IN THE
UNITED STATES.

BY

C. F. LANGWORTHY, PH. D., AND R. D. MILNER, PH. B.,
Of the Office of Experiment Stations.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1904.

LIST OF PUBLICATIONS OF THE OFFICE OF EXPERIMENT STATIONS ON THE FOOD AND NUTRITION OF MAN.

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- Bul. 55. Dietary Studies in Chicago in 1895 and 1896. Conducted with the cooperation of Jane Addams and Caroline L. Hunt, of Hull House. Reported by W. O. Atwater and A. P. Bryant. Pp. 76. Price, 5 cents.
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- Bul. 63. Description of a New Respiration Calorimeter and Experiments on the Conservation of Energy in the Human Body. By W. O. Atwater and E. B. Rosa. Pp. 94. Price, 10 cents.
- *Bul. 66. The Physiological Effect of Creatin and Creatinin and their Value as Nutrients. By J. W. Mallet. Pp. 24. Price, 5 cents.
- Bul. 67. Studies on Bread and Bread Making. By Harry Snyder and L. A. Voorhees. Pp. 51. Price, 10 cents.
- Bul. 68. A Description of Some Chinese Vegetable Food Materials and Their Nutritive and Economic Value. By W. C. Blasdale. Pp. 48. Price, 10 cents.
- Bul. 69. Experiments on the Metabolism of Matter and Energy in the Human Body. By W. O. Atwater and F. G. Benedict, with the cooperation of A. W. Smith and A. P. Bryant. Pp. 112. Price, 10 cents.
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[Continued on third page of cover.]

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
A. C. TRUE, Director.

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NUTRITION INVESTIGATIONS.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., May 25, 1904.

SIR: I have the honor to transmit herewith and recommend for publication a summary showing the scope of the cooperative nutrition investigations carried on under the auspices of this Office. This includes an account of the origin and development of the investigations and their character, data regarding the collaborators and collaborating institutions, and also some of the more important results obtained.

Respectfully, ,

A. C. TRUE,
Director.

Hon. JAMES WILSON,
Secretary of Agriculture.

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INVESTIGATIONS ON THE NUTRITION OF MAN IN THE UNITED STATES.

By C. F. LANGWORTHY, Ph. D., and R. D. MILNER, Ph. B.,
Of the Office of Experiment Stations.

INTRODUCTION.

During the past few years the experimental study of the food and nutrition of both domestic animals and man has become very active in the United States. A large part of such inquiry, indeed nearly all of that which has to do with domestic animals, is carried on in connection with the agricultural experiment stations, which have been established within the past twenty-eight years and are now in operation in all the States and Territories of the Union except the Philippines.

With the rise of the experiment stations inquiries into the composition of feeding stuffs and their appropriate use in the nutrition of domestic animals were undertaken, and have ever since been carried on quite actively. Later some of the stations undertook similar investigations of the food of man, and in recent years the study of the food and nutrition of man has acquired increased importance in the United States from the extensive investigations that have been made and are still being made in connection with and as a part of the work of the Department of Agriculture in cooperation with universities, colleges, experiment stations, benevolent institutions, and individual investigators in different parts of the country.

There had been, indeed, a considerable amount of study of the food of man—and of domestic animals also—before the experiment stations were established. An interesting investigation on the subject of human nutrition was prosecuted by J. R. Young, in Philadelphia, as early as 1803, and perhaps almost continuously since that time valuable information on food and nutrition has been accumulated by physicians, by State boards of health, and by specialists in physiology, hygiene, and dietetics. The United States Government, through its various branches, has contributed much of value to the science of nutrition. The War Department and the Navy Department, in their efforts to secure the most satisfactory diet for the soldiers and sailors, have collected a great deal of information and conducted many investigations which have to do with the subject of dietetics, while the

importance of their investigations dealing with the hygiene of the subject can hardly be overestimated. In connection with the United States Census a large amount of data regarding foods has been secured, the major portion of which has to do with production and distribution, though many analyses have been reported in census publications, as well as special studies of foods, food industries, and related topics. Of very noteworthy importance are the studies of analytical methods, of the chemical composition of foods, and of food adulteration, conducted in the Bureau of Chemistry of the Department of Agriculture by its chief, Prof. H. W. Wiley, and others.

A complete historical review of investigations on food and nutrition of man in the United States would necessarily include an account of the above inquiries and others not referred to here. The purpose of the present article, however, is to give a brief résumé of the cooperative inquiry into the food and nutrition of man now being carried on under the auspices of the Office of Experiment Stations of the Department of Agriculture, and to indicate the progress and results of that enterprise. This inquiry had its inception in a study of the chemical composition of food fishes and invertebrates undertaken by Prof. W. O. Atwater in 1877 and continued until 1882, in the chemical laboratory of Wesleyan University, Middletown, Conn., at the instance of Prof. S. F. Baird, Secretary of the Smithsonian Institution and United States Commissioner of Fish and Fisheries. In connection with this work similar investigations of other animal and some vegetable products were undertaken a little later (1884) on behalf of the United States National Museum. About the same time (1886) the first extended inquiry into the statistics of food consumption in the United States was undertaken by Hon. Carroll D. Wright, as chief of the Massachusetts Bureau of Statistics of Labor, and the chemical results were computed and reported by Professor Atwater. In 1890 the Connecticut (Storrs) Experiment Station, under the direction of Professor Atwater, in cooperation with Hon. Carroll D. Wright as United States Commissioner of Labor, began a series of dietary studies which continued for several years. Except for the inquiries under the auspices of the Massachusetts labor bureau, the United States Department of Labor, and the Connecticut (Storrs) Experiment Station, the larger share of the expenses of this work was borne by private individuals. The results of these inquiries gradually attracted attention. The bearing of such research upon household, agricultural, and national economics became evident, and as early as 1890 steps were taken to secure an appropriation from Congress to enlarge its scope and usefulness, but nothing definite was accomplished there until 1894. In that year the experiment stations were authorized by Congress to cooperate with the Secretary of Agriculture in studying the food and nutrition of man, and were called upon to report to him the results of

such investigations as they might carry out. At the same time Congress provided an especial appropriation to enable the Secretary of Agriculture to prosecute inquiries in this direction. The sums provided by Congress for nutrition investigations for the Department of Agriculture have been since the beginning:

Fiscal year.	Amount.	Fiscal year.	Amount.
1894-95	\$10,000	1900-1901	\$17,500
1895-96	15,000	1901-2	20,000
1896-97	15,000	1902-3	20,000
1897-98	15,000	1903-4	20,000
1898-99	15,000	1904-5	20,000
1899-1900	15,000		

These amounts have been increased by contributions from other sources which are not easily estimated in terms of money, since they consist in large part of the use of laboratories, apparatus, and other facilities for research, the counsel and help of experts, and other gratuitous service. The State of Connecticut makes an annual appropriation, which is used under Professor Atwater's direction, for nutrition investigations, in cooperation with the United States Department of Agriculture. Part of the appropriation made by the State of Illinois to its State University and experiment station is regularly expended in the study of problems related to the food and nutrition of man. A considerable number of other experiment stations, educational institutions, philanthropic organizations, and private individuals have given sums of money to promote the cooperative inquiry.

ORGANIZATION OF THE INQUIRY.

The nutrition investigations of the Department of Agriculture are conducted through the Office of Experiment Stations, the general supervision of these investigations having been assigned by the Secretary of Agriculture to that Office. The immediate supervision of the enterprise has been entrusted to Prof. W. O. Atwater, chief of nutrition investigations.

For many years Professor Atwater, in connection with his duties as professor of chemistry at Wesleyan University, has devoted much of his time to investigations relating to the nutrition of man, introducing into the United States the German methods of studying nutrition problems. He was the first director of the Office of Experiment Stations, and, after his services in this capacity had terminated, the Department was very fortunate in securing his cooperation as special agent in charge of its nutrition investigations. The very great development of this enterprise, as evidenced by the number and extent of the investigations carried on, the public interest which has been aroused, the demand for information from private individuals, physicians, and teachers, and the practical application of the results already obtained

in numerous instances where rational and economical feeding was a necessity, are indications that the investigations have been well managed.

The administrative and editorial work connected with the nutrition investigations is conducted at Washington, D. C., and Middletown, Conn. The investigations themselves are prosecuted in different places, the general policy being to make particular institutions centers of investigations along special lines. Part of the fund provided by Congress is expended under the sole and immediate care of the Department; part is distributed among scientific, educational, and philanthropic institutions in various places from Maine to California, and used not so much as compensation for services as for encouragement to research. The cooperating institutions have in most cases contributed material assistance, especially as regards laboratory rooms and appliances and the services of skilled investigators.

SCOPE OF THE INQUIRY.

Investigations on the food and nutrition of man include the study of two branches of the subject, which, though quite intimately related and both valuable, are nevertheless of importance in different ways. One branch comprises a study of the chemical composition of different food materials, an investigation that is purely analytical, but a necessary preliminary to studies in the other branch of the subject, which comprises researches into the laws of nutrition. The former is concerned simply with the chemistry of food, while the latter has to do with the physiology, the physics and chemistry, of the nutrition of man, together with the economic and sociological application of the fundamental principles of nutrition to the diet of persons in different localities and under different conditions in life.

The cooperative nutrition investigations include studies of several branches of the subject, especial attention having been paid to studies of the kinds and amounts of food consumed by individuals, families, institutions, etc.; experiments on the digestibility of food materials; and researches into the fundamental laws of nutrition, including particularly investigations with the bomb calorimeter and the respiration calorimeter. In addition to these, collateral questions of a wide variety have also received much attention. A brief statement of the general lines along which the inquiries have been conducted is as follows:

Studies of actual dietaries in order to learn the kinds, amounts, and costs of food materials consumed by persons in different localities, of different occupations, ages, and sex, and under varying conditions.

Special studies of cereal products, including nutritive value of different milling products of wheat; nutritive value, quality, and digestibility of bread from hard and soft wheat flours of different grades, as "graham," "entire wheat," and "standard patent" grades; bakery experiments to determine the cost of making bread, and the



FIG. 1.—BREAD FROM NORMAL FLOUR AND FROM MIXTURES OF NORMAL AND EXTRACTED FLOURS.

A, Normal flour; B, flour with about one-half of the gliadin extracted; C, one-half normal and one-half gliadin-extracted flour.



FIG. 2.—BREAD FROM NORMAL FLOUR AND FROM MIXTURES OF NORMAL AND CORN FLOURS.

A, Normal flour; B, normal flour and 20 per cent corn flour; C, normal flour and 10 per cent corn flour.

losses in nutritive value during the process of bread making. Plate I illustrates the results obtained in some of these studies of the effect and the importance of the various constituents of flour upon the character of the bread. In fig. 1, bread A was made from normal flour and breads B and C from flour which contained abnormal amounts of gliadin, one of the important nitrogenous constituents of flour. In fig. 2, A represents normal bread and B and C bread made from flour in which the starch content was rendered abnormal by adding corn flour.

Special studies of meats, including the nutritive value of raw and cooked meats; the relative digestibility of meats cooked in different ways; the nature and amount of losses occurring during the cooking of meats in different ways.

Experiments on the digestibility of vegetables and the losses in different vegetables during cooking.

Experiments on the digestibility and nutritive value of legumes, including beans and cowpeas.

Studies of the comparative economy, digestibility, and nutritive value of fruits and nuts.

A convenient and comparatively inexpensive form of bomb calorimeter has been developed and is used in determining the amounts of potential energy in food materials, excretory products, and other substances.

Metabolism experiments have been carried on with men in the respiration calorimeter. The objects of these investigations have been: To develop an apparatus and method for the accurate measurement of the income and outgo of the animal organism as expressed in terms of matter and energy; to confirm the belief that the law of the conservation of energy obtains in the living body; and, after such demonstration of the accuracy of the apparatus and methods and of the action of the law of the conservation of energy, to study some of the more important fundamental laws of nutrition.

The fact was early recognized that compilations and summaries of the investigations which have been carried on in Europe and this country were necessary. In order to conduct any kind of research most efficiently it is necessary to know what has been accomplished by others in order that the investigator may profit by their results and that an unnecessary duplication of effort may be avoided. Furthermore, summaries of previous investigations are of great value in suggesting lines of research and in awakening the interest of investigators by showing past achievements. To this end the current literature of the nutrition of man, which is now quite voluminous, is being regularly followed up, and such abstracts and compilations are being made as will promote the interest of the investigations.

The rapid accumulation of material which must be made ready for publication necessitates a large amount of editorial work. The results of the investigations are given in bulletins, some of popular nature and others technical in character. The results of analyses of food materials in the United States have been compiled and printed in a bulletin for popular use, which is revised from time to time as data accumulate. The results of dietary studies also appear in bulletins prepared for popular use. The data of the digestion experiments and those obtained in investigations with the respiration calorimeter are given in bulletins more or less technical in character, and intended rather for the scientific student of the subject. Abstracts of the current literature of the subject of food and nutrition appear regularly in the Experiment Station Record. More popular abstracts of some of this work, particularly that of American investigators, appear in the series of Farmers' Bulletins, entitled "Experiment Station Work."

The correspondence connected with the nutrition investigations has grown to very considerable dimensions.

DISTRIBUTION OF THE WORK.

The following is a brief summary, alphabetically by States, of the localities in which the inquiries have been prosecuted, the cooperating institutions and investigators, and the nature of the investigations conducted:

Alabama.—Tuskegee Normal and Agricultural Institute; Prof. Booker T. Washington. Alabama Polytechnic Institute and the Alabama Experiment Station, Auburn; Prof. B. B. Ross. Study of the food consumption of the negroes in the "black belt" of Alabama, and of the character and nutritive value of the food materials used by negroes.

California.—University of California; Prof. M. E. Jaffa. Cost and nutritive value of California food materials, especially fruits and nuts; dietary studies of infants, athletes, professional men, fruitarians, and Chinese; digestion and nitrogen metabolism experiments with an infant and with fruitarians.

In addition, Mr. W. C. Blasdale, instructor in chemistry at the university, made a detailed study of the nutritive and economic value of Chinese vegetable food materials found in the markets of San Francisco.

Connecticut.—Wesleyan University and Storrs Experiment Station; Prof. W. O. Atwater, Prof. F. G. Benedict, and associates. Cost and nutritive value of various food materials; dietary studies; digestion and nitrogen metabolism experiments; development of bomb calorimeter and respiration calorimeter, and of methods of using these in investigations of the metabolism of matter and energy in the human body.

The work of the office of Professor Atwater, who is chief of the nutrition investigations, has also included the planning and direct supervision of the cooperative investigations in different parts of the country, the compilation of the results of nutrition investigations in the United States and foreign countries, editorial work in the preparation of the reports of the cooperators for publication, and a large correspondence relating to the investigations.

Georgia.—University of Georgia; Dr. H. C. White. Dietary studies of college boarding, clubs, and of families in the mountain regions of Georgia.

Illinois.—Hull House, Chicago; Miss Jane Addams and Miss Caroline Hunt; and Lewis Institute, Chicago; Prof. G. N. Carman. Dietary studies.

Mrs. Ellen H. Richards and Miss Amelia Shapleigh also carried on dietary studies with the cooperation of Hull House. The data obtained were eventually submitted to the Department of Agriculture for calculation and publication.

University of Illinois; Prof. H. S. Grindley. Cost and nutritive value of food materials; dietary studies; special investigations on meat, including losses in different modes of cooking, and digestibility of meats cooked in different ways. Prof. Isabel Bevier and Miss Elizabeth Sprague. Studies in cooking meat.

Indiana.—Purdue University; Prof. W. E. Stone. Dietary studies.

Maine.—University of Maine and Maine Experiment Station; Prof. W. H. Jordan, Prof. C. D. Woods, and L. H. Merrill. Studies of the nutritive value of a number of food materials; feeding experiments to determine the value of milk in the diet; and dietary studies and digestion experiments, especially with lumbermen in the Maine woods. Experiments on the digestibility and nutritive value of bread made from different grades of flour; study of experimental methods, particularly means of separation of feces in digestion experiments and determination of metabolic nitrogen in feces.

Maryland.—Mrs. Mary Hinman Abel cooperated with the Department in the preparation of summaries of data regarding the nutritive value and place in the diet of sugar and of leguminous vegetables, and in connection with this work made a number of cooking experiments.

Massachusetts.—School of Housekeeping, Boston; Miss Lydia Southard, Miss Susannah Usher, and Miss Bertha M. Terrill carried on dietary studies, in a number of which the attempt was made to regulate the cost of the food and at the same time make it compare with commonly accepted dietary standards. The results of these investigations were submitted to the Department for calculation and publication.

Harvard University, Cambridge; Dr. E. A. Darling. Dietary studies of athletes. Prof. C. R. Sanger and Mr. Edward Mallinckrodt, jr. Dietary studies of students.

Springfield Bible Normal College; Miss Bertha M. Terrill. Dietary study. In this investigation the attempt was made to regulate the cost of the daily food and at the same time make it correspond with the commonly accepted dietary standards. The results were submitted to the Department for calculation and publication.

Minnesota.—University of Minnesota and Minnesota Experiment Station; Prof. Harry Snyder. Study of losses in cooking vegetables and in making bread; special studies of cereal products, including relative nutritive value of milling products of wheat, and digestibility and nutritive value of bread made from different grades of hard and soft wheat flours. A considerable part of the latter investigation is carried on coordinately with similar work by Prof. C. D. Woods at the Maine Experiment Station.

Missouri.—University of Missouri; Prof. H. B. Gibson. Dietary studies; investigation of the relative consumption of different kinds of meat and bread.

New Jersey.—New Jersey Experiment Station; Prof. E. B. Voorhees and Mr. L. A. Voorhees. Dietary study; studies of the cost and composition of milk and of bread, of the relative cost of bread and the raw ingredients from which it was made, and of the losses in baking bread.

New Mexico.—New Mexico College of Agriculture and Mechanic Arts and New Mexico Experiment Station; Prof. Arthur Goss. Study of the relative nutritive value of native food materials, especially native beef, and of the food consumption of native Mexican families.

New York.—Mrs. Louise E. Hogan studied the history and methods of teaching cookery in the public schools of New York City.

Cornell University, Ithaca; Prof. R. C. Carpenter. Measurements of mechanical work, and studies of the efficiency of man as a machine.

New York Association for the Improvement of the Condition of the Poor and New York Christian Alliance, New York; Dr. Isabelle Delaney. Dietary studies of poor families in congested districts in New York City.

Columbia University, New York; Dr. H. C. Sherman. Digestion experiments and investigations on the metabolism of nitrogen, sulphur, and phosphorus in the human body.

North Dakota.—North Dakota Agricultural College; Prof. E. F. Ladd. Dietary study.

Ohio.—Lake Erie College; Prof. Isabel Bevier and Miss Elizabeth Sprague. Dietary study.

Pennsylvania.—College Settlement, Philadelphia; Mrs. Ellen H. Richards and Miss Amelia Shapleigh. Dietary studies of families of limited income were undertaken, the data obtained being submitted to the Department for calculation and publication.

Pennsylvania College for Women, Pittsburg; Prof. Isabel Bevier. Dietary studies; study of the composition and cost of bakers' bread in Pittsburg and of the changes in the materials of bread during baking.

Tennessee.—University of Tennessee; Prof. C. E. Wait. Analyses of Tennessee food materials; dietary studies; experiments on the effect of muscular work upon the digestibility of food and the metabolism of nitrogen; studies of the digestibility and nutritive value of legumes.

Vermont.—Vermont Experiment Station; Prof. J. L. Hills. Dietary studies of farmers' families.

Virginia.—Hampton Normal and Agricultural Institute; Dr. H. B. Frissell. Dietary studies of negroes.

Under special authorization Miss Isabel Bevier also made similar studies in another part of the State.

State University; Prof. J. W. Mallett. Studies of the physiological effects of meat bases, i. e., creatin and creatinin.

Washington, D. C.—Besides the general supervision of the plans and expenditures the work of the Washington office in relation to the nutrition investigations has included the preparation of popular bulletins; the compilation of technical summaries of investigations; editorial work in perfecting the details of reports of investigations; collection of bibliographical data; the abstracting of the literature of nutrition, partly for publication in the Experiment Station Record; the conducting of a large correspondence growing out of nutrition investigations, and the distribution of publications on this subject. This work is in charge of Dr. C. F. Langworthy.

Cooperating with the U. S. Department of the Interior a series of studies of food consumption has been conducted in the Government Hospital for the Insane at Washington, D. C. The results obtained were interesting and valuable, and are being utilized to make the diet, which was found to be ample and of good quality, conform to theoretical requirements. This cooperative investigation was begun by Dr. A. B. Richardson and was continued by his successor, Dr. W. A. White, the experimental work having been carried on by Mr. H. A. Pratt.

Mention should also be made here of other investigations which, while not strictly a part of the cooperative inquiry, are yet so closely related to it that they may be included in this summary:

On behalf of the New York State Commission in Lunacy an extended series of studies of the food consumption of the New York hospitals for the insane was carried on under the supervision of Professor Atwater.

A study of the food consumption at the Elmira Reformatory, in New York State, was also made under the supervision of Professor Atwater.

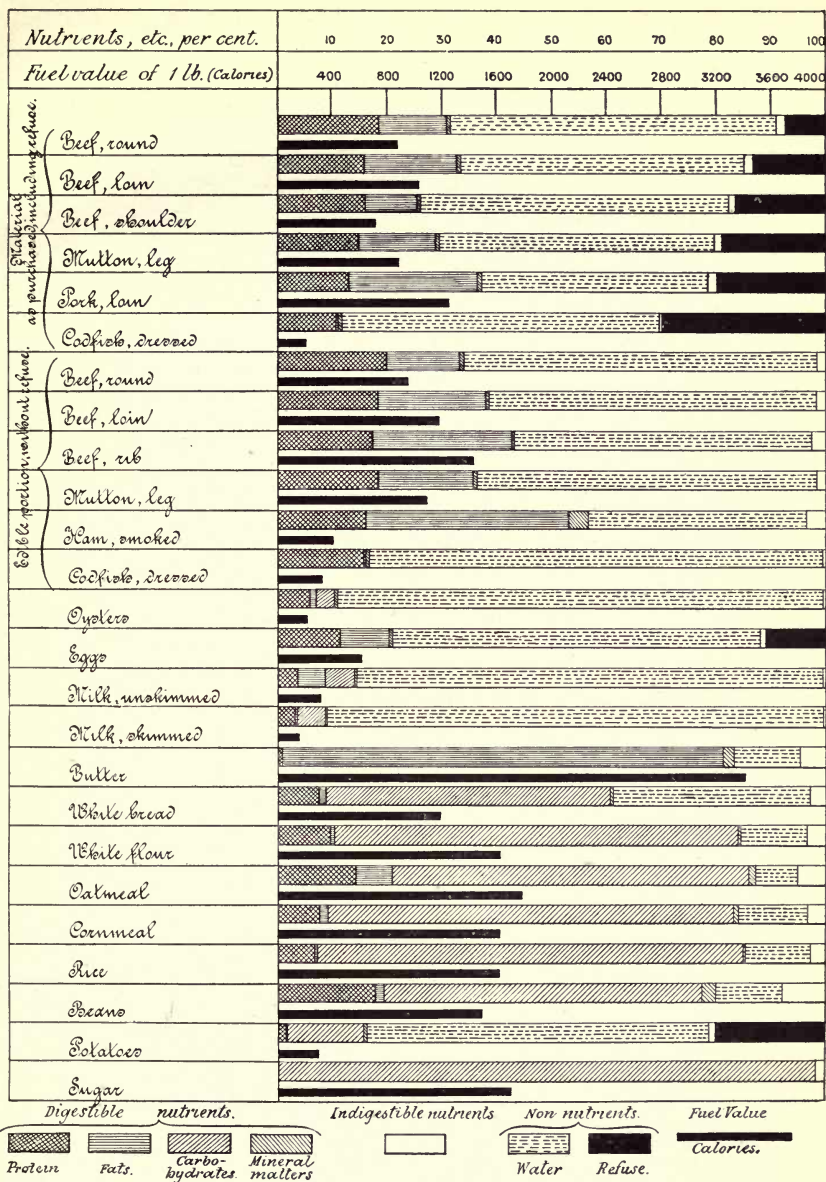
A sum of money has been granted by the Carnegie Institute to Professor Atwater for the development of accessory apparatus and methods for determination of oxygen in connection with the experiments in the respiration calorimeter, and for investigations of the income and outgo of oxygen in the animal organism. The apparatus has been completed and found to be very accurate (see p. 16).

SOME RESULTS OF NUTRITION INVESTIGATIONS.

Among the more important results obtained in these investigations are those from studies of the composition of food material, from dietary studies, digestion experiments, and investigations with the respiration calorimeter.

COMPOSITION OF FOOD MATERIALS.

One result of the investigations of food and nutrition in the United States, including both the work done as a part of the cooperative inquiry and that carried on in other connections, is that we have now a tolerably clear idea of the composition and nutritive values of our ordinary American food materials. In the latest revised edition of a



COMPOSITION OF FOOD MATERIALS. NUTRITIVE INGREDIENTS, REFUSE, AND FUEL VALUE.



DINNER AT A CHINESE TRUCK FARM, CALIFORNIA.

bulletin^a published in 1903, in which these results are compiled, the total number of analyses included was 4,063. Of these, 1,618 were of animal foods, 2,375 of vegetable foods, and 70 of unclassified foods.

At the present time the number of analyses thus compiled is more than 4,500 and is still rapidly increasing. They are now derived more largely from other sources than the cooperative nutrition investigations, because in connection with the latter they are made only when necessary, as in digestion and metabolism experiments. They are no longer made simply to increase the amount of such data available. Plate II shows in graphic form the composition and fuel value of some of the more common food materials.

DIETARY STUDIES.

The number of studies of the actual food consumption of people of different classes that have formed part of the cooperative inquiry in different parts of the United States is now over 500. These include studies of families of day laborers, farmers, mechanics, and men in professional life; of people in congested districts of the slums of New York and Chicago, and poor families in other cities; of negroes in the South; of Spaniards in the extreme Southwest; and of Chinese and fruitarians on the Pacific coast. In a large number of these studies actual analyses were made of food materials and of waste. In addition to the above, which were made entirely as a part of the cooperative nutrition investigations, nearly half as many studies of a similar nature not directly related to the cooperative inquiry have also been completed. The latter include studies in private families, in boarding houses and clubs of men and women in colleges, in hospitals for the insane, and in other institutions. The total number of persons—men, women, and children—included in all these studies is not far from 15,000.

Results of some of the more important dietary studies thus far made are summarized in the following table. These are typical of the studies already published. The data of a considerable number of other studies are now being prepared for publication.

^aU. S. Dept. Agr., Office of Experiment Stations Bul. 28: The Chemical Composition of American Food Materials. Revised edition, 1903.

Summarized results of dietary studies in the United States.

[Quantities per man per day.]

	Number of studies included in averages.	Actually eaten.			Digestible.			Fuel value.	Nutritive ratio.
		Protein.	Fat.	Carbohydrates.	Protein.	Fat.	Carbohydrates.		
PERSONS WITH ACTIVE WORK.									
Rowing clubs in New England.....	7	Gms. 155	Gms. 177	Gms. 440	Gms. 143	Gms. 168	Gms. 427	Cals. 3,955	1: 5.6
Bicyclists in New York.....	3	186	186	651	171	177	631	5,005	6
Football teams in Connecticut and California	2	226	354	634	208	336	615	6,590	6.6
PERSONS WITH ORDINARY WORK.									
Farmers' families	10	97	130	467	89	124	453	3,415	8.2
Mechanics' families	14	103	150	402	95	143	390	3,355	7.5
Laborers' families in large cities.....	12	101	116	344	93	110	334	2,810	6.3
Laborers' families in more comfortable circumstances.....	2	120	147	534	110	140	518	3,925	7.6
PROFESSIONAL MEN.									
Lawyers, teachers, etc.....	14	104	125	423	96	119	410	3,220	7.1
College clubs	15	107	148	459	98	141	445	3,580	7.8
MEN WITH LITTLE OR NO EXERCISE.									
Men in respiration calorimeter.....	11	112	80	305	103	76	296	2,380	4.5
PERSONS IN DESTITUTE CIRCUMSTANCES.									
Poor families in New York City.....	11	93	95	407	86	90	395	2,845	6.9
Laborers' families in Pittsburg, Pa.....	2	80	95	308	74	90	299	2,400	6.8
MISCELLANEOUS.									
Negro families in Alabama.....	20	62	132	436	57	125	423	3,165	12.4
Negro families in Virginia	19	109	159	444	100	151	342	3,625	6.8
Italian families in Chicago.....	4	103	111	391	95	105	379	2,965	6.5
French Canadians in Chicago.....	5	118	158	345	109	150	335	3,260	6.2
Bohemian families in Chicago.....	8	115	101	360	106	96	349	2,800	5.3
Inhabitants of Java Village, Columbian Exposition, 1893.....	1	66	19	254	61	18	246	1,450	4.7
Russian Jews in Chicago.....	10	137	103	418	126	98	405	3,135	5
Mexican families in New Mexico.....	4	94	71	613	86	67	595	3,460	8.7
Chinese dentist in California.....	1	115	113	289	106	107	281	2,620	4.9
Chinese laundrymen in California.....	1	135	76	566	124	72	549	3,480	5.7
Chinese farm laborers in California.....	1	144	95	640	132	90	621	3,980	6.2
Fruitarians.....	6	50	102	237	43	92	225	2,055	10
DIETARY STANDARDS.									
Man with very hard muscular work (Atwater).....	175	(a)	(a)	161	(a)	(a)	5,500	7.2	
Man with hard muscular work (Atwater).....	150	(a)	(a)	138	(a)	(a)	4,150	6.2	
Man with moderately active muscular work (Atwater).....	125	(a)	(a)	115	(a)	(a)	3,400	6.2	
Man with light to moderate muscular work (Atwater).....	112	(a)	(a)	103	(a)	(a)	3,050	6.1	
Man at "sedentary" or woman with moderately active work (Atwater).....	100	(a)	(a)	92	(a)	(a)	2,700	6.1	
Woman at light to moderate muscular work (Atwater).....	90	(a)	(a)	83	(a)	(a)	2,450	6.1	

a Fats and carbohydrates in sufficient amounts to furnish, together with the protein, the indicated amount of energy.

The figures in the above table show both the total nutrients in the food consumed, as calculated from the weights and chemical composition, and the digestible nutrients as estimated by use of coefficients of digestibility based upon the results of digestion experiments. The

fuel value of the diet—i. e., the amount of energy actually available to the body—has been calculated by the use of the most recent factors for fuel value of nutrients. The table also shows dietary standards that have been proposed on the basis of the data obtained in dietary studies, digestion experiments, and investigations with the respiration calorimeter.

From the results of these investigations it is apparent that variations in diet are in part such as naturally follow differences in the actual food supply; but they are also influenced to some extent by race habits, and to a still larger extent by the amount of muscular work performed and by the material circumstances of the consumer, including especially his income.

One of the most important ways in which practical application may be made of the results of these studies to the benefit of large numbers of people is in teaching the relative nutritive value of different food materials and their pecuniary economy. Much is already being done in this direction in different parts of the United States.

The proper nourishment of the inmates of institutions where large numbers must be fed, such as schools, reformatories, prisons, and hospitals, is a subject that is attracting no little attention at the present time. In many instances dietary studies have been made in schools, college clubs, etc., and the information obtained has been of much use. That such studies have been found to have a practical value, and that the interest in them is widespread, is shown by the fact that a considerable number have been undertaken by instructors and others interested, aside from those carried on by the Department of Agriculture. The dietary studies were made under widely varying conditions. Plate III, showing Chinese farm laborers at dinner, is an illustration of this. These laborers were one of the groups studied in an investigation of the dietary of Chinese on the Pacific coast.

As a result of such studies as those described above, the dietary standards included in the table have been suggested. These are intended to show the actual food requirements of persons under different conditions of life and work, and how these requirements may be most economically and efficiently supplied by the available food materials. It is not claimed, however, that the food each day should contain exactly the kind and amounts of the different nutrients required by the standards. A slight deficiency one day will be made good by an excess the next, the body serving as a storehouse for reserve material. Experience has, however, shown that the body is best nourished when through long periods the food approximates the requirements of the so-called standards. Individual requirements and individual peculiarities will always affect the choice of foods.

The exact knowledge which comes with such researches is showing how the diet of large classes of our population may be materially improved while often its cost may be considerably reduced.

DIGESTION EXPERIMENTS.

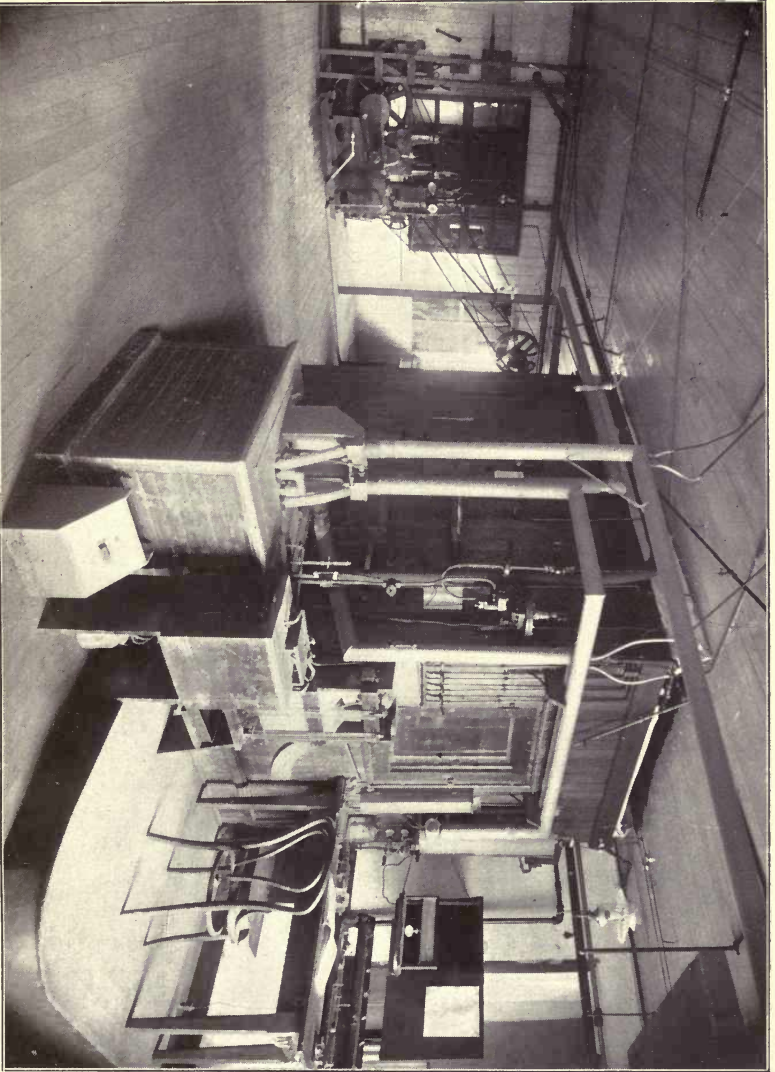
Nearly 600 digestion experiments, mostly with men but a few with women and children, have been made in connection with the nutrition investigations of the Department. In connection with nearly half of these the income and outgo of nitrogen has been determined, thus making them nitrogen metabolism experiments also.

The results of these digestion experiments show the digestibility of various sorts of mixed diet and of individual food materials. Taking these results into account, together with the results of analyses, we are able to prepare tables showing the average quantities of digestible nutrients in a large number of the food materials in most common use.

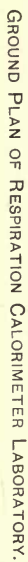
METABOLISM EXPERIMENTS WITH THE RESPIRATION CALORIMETER.

From the more purely scientific standpoint, the interest of this cooperative nutrition inquiry culminates in the experiments with the respiration calorimeter. These have for their object the study of the transformation of matter and energy in the living organism. In other words, they represent an inquiry into the most fundamental and most important laws of nutrition. The apparatus used for the purpose, known as the Atwater-Rosa respiration calorimeter, which has been developed in connection with these investigations, suffices for the accurate measurement of the income and outgo of all chemical elements except oxygen, of the potential energy of food, of unoxidized excretory products, of body material gained or lost, and of the kinetic energy given off from the body in the forms of heat and external muscular work. Accessory apparatus and a method for the direct determination of income and outgo of oxygen have very recently been completed by Professors Atwater and Benedict, and it is possible with the calorimeter as thus modified to determine directly all the elements of income and outgo and in addition to study the respiratory quotient which is known to be a very delicate index of the processes going on in the body. Plate IV gives a general view of the respiration calorimeter, and Plate V a ground plan of the calorimeter laboratory.

One very important result thus far obtained by the use of this apparatus is what amounts practically to a demonstration that the law of the conservation of energy applies to the living organism. The proof that this law obtains in the inorganic world was one of the great scientific achievements of the last century. It has, of course, been assumed and very generally believed that it must also apply in the organic world—in the living being; but a complete and satisfactory demonstration has not hitherto been made, although an approximate proof was found in a number of European experiments with dogs. As the outcome of 64 experiments by Professors



GENERAL VIEW OF THE RESPIRATION CALORIMETER.



Atwater and Benedict, and their associates, at Wesleyan University, made with 6 different men, covering an aggregate of one hundred and eighty-four days, the ratio of the potential energy of the material oxidized in the body to the energy given off from the body in the forms of heat and muscular work, as measured by the respiration calorimeter, is as 1,000 to 999. The same ratio of 1,000 to 999 was found in the average of a large number of experiments made to test the accuracy of the apparatus. Closer agreement than this could not be looked for.

The practical usefulness of this apparatus and method of inquiry will be realized more clearly when we consider that it gives us a means for measuring more exactly than has hitherto been possible, the transformations of matter and energy which take place in the bodies of different persons with different kinds and amounts of food or in fasting, and under widely varying conditions of muscular and mental activity. The experiments furnish a mass of data needed for various sciences of physiology and hygiene. These data have to do with food, drink, and excretory products and with the metabolic processes and changes of body tissue as they are influenced by work, sleep, diet, temperature, and other circumstances. They show the nutritive values of food and the demands of the body in health and disease. Incidentally they throw valuable light on problems of ventilation and numerous other questions of hygiene. They supply the foundations of the doctrine of nutrition and belong to the highest order of scientific research.

FACTORS FOR DIGESTIBILITY AND FUEL VALUE OF NUTRIENTS.

The data obtained in the nutrition investigations may be used in deducing certain factors which are useful in various ways to students and investigators of similar problems, and to some extent also to those who wish to make practical application of the results. Such factors for the digestibility and fuel value of the nutrients of ordinary mixed diet have been epitomized by Professor Atwater in the following table:

Factors for digestibility and fuel value of nutrients in mixed diet.

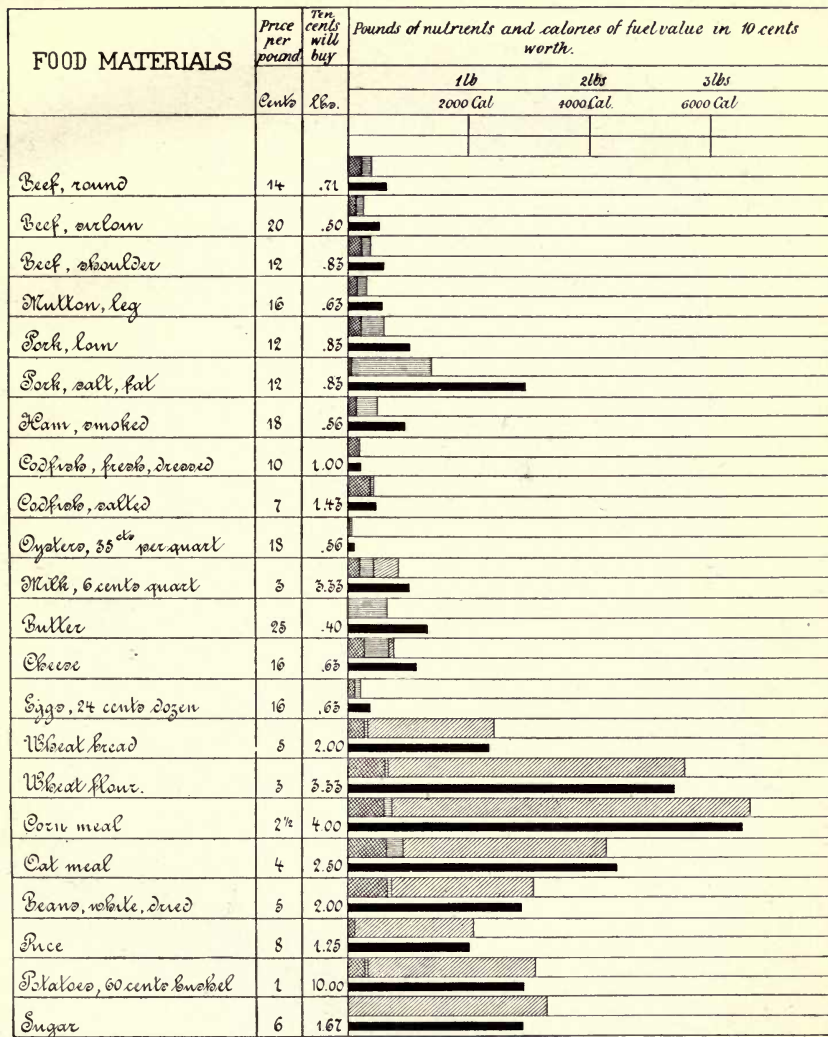
Classes of food materials.	Protein.				Fat.				Carbohydrates.				Proportion of total energy actually available.
	Proportion of total in mixed diet.	Digestibility.	Fuel value per gram.		Proportion of total in mixed diet.	Digestibility.	Fuel value per gram.		Proportion of total in mixed diet.	Digestibility.	Fuel value per gram.		
			Total nutrients.	Digestible nutrients.			Total nutrients.	Digestible nutrients.			Total nutrients.	Digestible nutrients.	
Meat and fish.....	43	97	4.27	4.40	60	95	9.03	9.50	5	98	3.82	3.90	87
Eggs.....	6	97	4.37	4.50									89
Dairy products.....	12	97	4.27	4.40	32	95	8.79	9.25					93
Animal food (of mixed diet).....	61	97	4.27	4.40	92	95	8.93	9.40	5	98	3.82	3.90	89
Cereals.....	31	85	3.87	4.55	8	90	8.37	9.30	55	98	4.11	4.20	91
Legumes (dried)....	2	78	3.47	4.45					1	97	4.07	4.20	83
Sugars.....									21	98	3.87	3.95	98
Starches.....										98	4.11	4.20	98
Vegetables.....	5	83	3.11	3.75					13	95	3.99	4.20	91
Fruit.....	1	85	3.36	3.95					5	90	3.60	4.00	88
Vegetable food (of mixed diet).....	39	85	3.74	4.40	8	90	8.37	9.30	95	97	4.03	4.15	92
Total food (of mixed diet).....	100	92	4.05	4.40	100	95	8.93	9.40	100	97	4.03	4.15	91

Briefly stated, on an average about 96 per cent of the total organic matter of mixed diet will be digested and 91 per cent of the energy will be available to the body; or, in other words, the body rejects about 4 per cent of the nutrients and about 9 per cent of the energy supplied by the food.

With the exception of some important European determinations of heats of combustion, the figures given in the above table are derived from late investigations in the United States. These included over 4,500 analyses of food materials; over 500 dietary studies; nearly 600 digestion experiments, mostly with men; several thousand determinations of heat of combustion of food materials and excretory products, and 64 experiments, covering in the aggregate 184 days, with men in the respiration calorimeter, besides a considerable number of other experimental inquiries, including especially the determinations of the constitution of protein compounds in various materials. The results of computations by means of these factors have been found to agree very closely with those obtained in actual experiments, showing that the factors are reasonably accurate.

THE PECUNIARY ECONOMY OF FOOD.

The sum expended for food is the principal item in the living expenses of a large majority of families, and yet very few of even the most intelligent housekeepers have clear ideas regarding the actual nutritive value of different food materials. Very generally, even those who endeavor to economize know little of the combinations which are best fitted for nourishment and have still less information as to the

Protein.*Fats.**Carbohydrates**Fuel Value.*

PECUNIARY ECONOMY OF FOOD. AMOUNTS OF ACTUALLY NUTRITIVE INGREDIENTS
OBTAINED IN DIFFERENT FOOD MATERIALS FOR 10 CENTS.

Amounts of nutrients in pounds; fuel value in calories.

relation between the true nutritive value of foods and their cost. Of the different food materials which are palatable, nutritious, and otherwise suited for nourishment, the consumer wishes to know what ones are pecuniarily the most economical; in other words, which foods furnish the largest amounts of available nutrients at the lowest cost. In answering this question it is necessary to take into account not only the prices per pound, quart, or bushel of the different materials, but also the kinds and amounts of the actual nutrients they contain and their fitness to meet the demands of the body for nourishment. The cheapest food is that which supplies the most nutriment for the least money. The most economical food is that which is cheapest and at the same time best adapted to the needs of the user.

In many of the nutrition investigations, especially the dietary studies carried on by this Department, the cost of food in relation to the nutrients furnished has been considered. Plate VI, which compares a number of common foods from a pecuniary standpoint, shows the amounts of the protein, fat, carbohydrates, and energy which 10 cents worth of each of the food materials selected will supply. In every case the assumed price per pound is an average value based upon a considerable amount of data collected in different localities.

THE EDUCATIONAL INFLUENCE OF THE NUTRITION INVESTIGATIONS.

If the practical usefulness of these investigations is important, the educational influence is no less so. This is manifesting itself in a number of ways, but most of all in bringing the results of the inquiry directly into schools. Taking all the public schools and the colleges in the country together, the number in which the results of these inquiries are being directly taught is relatively small. Nevertheless, the actual number of institutions in which teachers are including more or less of these results in their courses of instruction, especially in physiology, is numerically large and is growing with the most encouraging rapidity. It has been the policy of the Department to deal very generously with schools and with teachers in the distribution of nutrition publications. Not only in cities, but in rural districts, there is a large and rapidly growing demand from the schools for these publications. They appear to meet an actual want—one that has been rather dimly felt hitherto, but is now becoming much more definite. The most active call, as would naturally be expected, has been from teachers connected with technical schools or the technical departments of colleges and high schools. The demand, however, has been almost as great from schools of medicine.

That the time for the development of these inquiries is especially opportune is shown by the use made of the results in the teaching of what is called domestic economy, or household economics. This represents an educational movement of greater import than many realize.

The movement is coming in response to popular demand and has the earnest support of many of our leading educators, not a few of whom are emphatic in the expression of their belief in the wisdom of the popular demand and the possibility of making such instruction very useful, especially in courses for girls and young women. Educational experience shows that a certain time is required to bring any new subject first into scientific and then into pedagogic form. The science of food and nutrition has already assumed reasonably clear and accurate scientific form and is being rapidly brought into pedagogic form.

CONCLUSION.

One most important feature of these investigations is the cooperation with scientific, educational, and philanthropic institutions in so many parts of the country. Among the advantages of this method of cooperation several are especially worthy of mention. First, there is the larger economy and effectiveness of scientific efforts shown in the development of special methods of investigation, in the planning of general and special lines of inquiry, and in the comparison and publication of results. The cooperating investigators and institutions are contributors to the enterprise, and the spirit of cooperation thus becomes in itself an important agency for diffusing the results and insuring their most useful application. Another advantage is found in the fact that, while institutions and investigators have that liberty of initiative and action which is so essential for scientific research, the several inquiries are so coordinated, and investigators are so aided by counsel and by the collating of the results of inquiry elsewhere as to give both the individual investigations and the research as a whole far more influence and usefulness than would otherwise be possible. From the practical standpoint also there is an advantage in the fact that so many different institutions, representing the varied interests of people in widely separate regions, are united in the study of prevalent conditions and in efforts toward improvement. Besides this the funds provided by the Department are used economically and are supplemented by the resources of the institutions and often by means from other sources. Thus not only is a large amount of work being done, but the interest is widely extended and the results are given very great practical usefulness.

So it has come about that from modest beginnings, in which work was carried on largely with the aid of private individuals, these investigations under the auspices of this Department have assumed a magnitude quite out of proportion to their actual cost; have achieved a noteworthy significance in scientific, educational, sociological, and economic results; and by the extensive cooperation of individuals and institutions of various kinds with this Department a large amount of valuable work is being done in a systematic way, the results of which are made available to the public.

LIST OF PUBLICATIONS OF THE OFFICE OF EXPERIMENT STATIONS ON THE FOOD AND NUTRITION OF MAN—Continued.

- Bul. 89. Experiments on the Effect of Muscular Work upon the Digestibility of Food and the Metabolism of Nitrogen. Conducted at the University of Tennessee, 1897-1899. By C. E. Wait. Pp. 77. Price, 5 cents.
- Bul. 91. Nutrition Investigations at the University of Illinois, North Dakota Agricultural College, and Lake Erie College, Ohio, 1896-1900. By H. S. Grindley and J. L. Sammis, E. F. Ladd, and Isabel Bevier and Elizabeth C. Sprague. Pp. 42. Price, 5 cents.
- Bul. 98. The Effect of Severe and Prolonged Muscular Work on Food Consumption, Digestion, and Metabolism, by W. O. Atwater and H. C. Sherman, and the Mechanical Work and Efficiency of Bicyclers, by R. C. Carpenter. Pp. 67. Price, 5 cents.
- Bul. 101. Studies on Bread and Bread Making at the University of Minnesota in 1899 and 1900. By Harry Snyder. Pp. 65. Price, 5 cents.
- Bul. 102. Experiments on Losses in Cooking Meat, 1898-1900. By H. S. Grindley, with the cooperation of H. McCormack and H. C. Porter. Pp. 64. Price, 5 cents.
- Bul. 107. Nutrition Investigations among Frunitarians and Chinese at the California Agricultural Experiment Station, 1899-1901. By M. E. Jaffa. Pp. 43. Price, 5 cents.
- Bul. 109. Experiments on the Metabolism of Matter and Energy in the Human Body, 1898-1900. By W. O. Atwater and F. G. Benedict, with the cooperation of A. P. Bryant, A. W. Smith, and J. F. Snell. Pp. 147. Price, 10 cents.
- Bul. 116. Dietary Studies in New York City in 1896 and 1897. By W. O. Atwater and A. P. Bryant. Pp. 83. Price, 5 cents.
- Bul. 117. Experiments on the Effect of Muscular Work upon the Digestibility of Food and the Metabolism of Nitrogen. Conducted at the University of Tennessee, 1899-1900. By C. E. Wait. Pp. 43. Price, 5 cents.
- Bul. 121. Experiments on the Metabolism of Nitrogen, Sulphur, and Phosphorus in the Human Organism. By H. C. Sherman. Pp. 47. Price, 5 cents.
- Bul. 126. Studies on the Digestibility and Nutritive Value of Bread at the University of Minnesota in 1900-1902. By Harry Snyder. Pp. 52. Price, 5 cents.
- Bul. 129. Dietary Studies in Boston and Springfield, Mass., Philadelphia, Pa., and Chicago, Ill. By Lydia Southard, Ellen H. Richards, Susannah Usher, Bertha M. Terrill, and Amelia Shapleigh. Edited by R. D. Milner. Pp. 103. Price, 10 cents.
- Bul. 132. Further Investigations among Frunitarians at the California Agricultural Experiment Station. By M. E. Jaffa. Pp. 81. Price, 5 cents.
- Bul. 136. Experiments on the Metabolism of Matter and Energy in the Human Body, 1900-1902. By W. O. Atwater and F. A. Benedict, with the cooperation of A. P. Bryant, R. D. Milner, and Paul Merrill. Pp. 357. Price, 20 cents.
- Bul. 141. Experiments on Losses in Cooking Meat, 1900-1903. By H. S. Grindley and Timothy Mojonnier. Pp. 95. Price, 5 cents.
- Bul. 143. Studies on the Digestibility and Nutritive Value of Bread at the Maine Agricultural Experiment Station, 1899-1903. By C. D. Woods and L. H. Merrill. Pp. 77. Price, 5 cents.

FARMERS' BULLETINS.

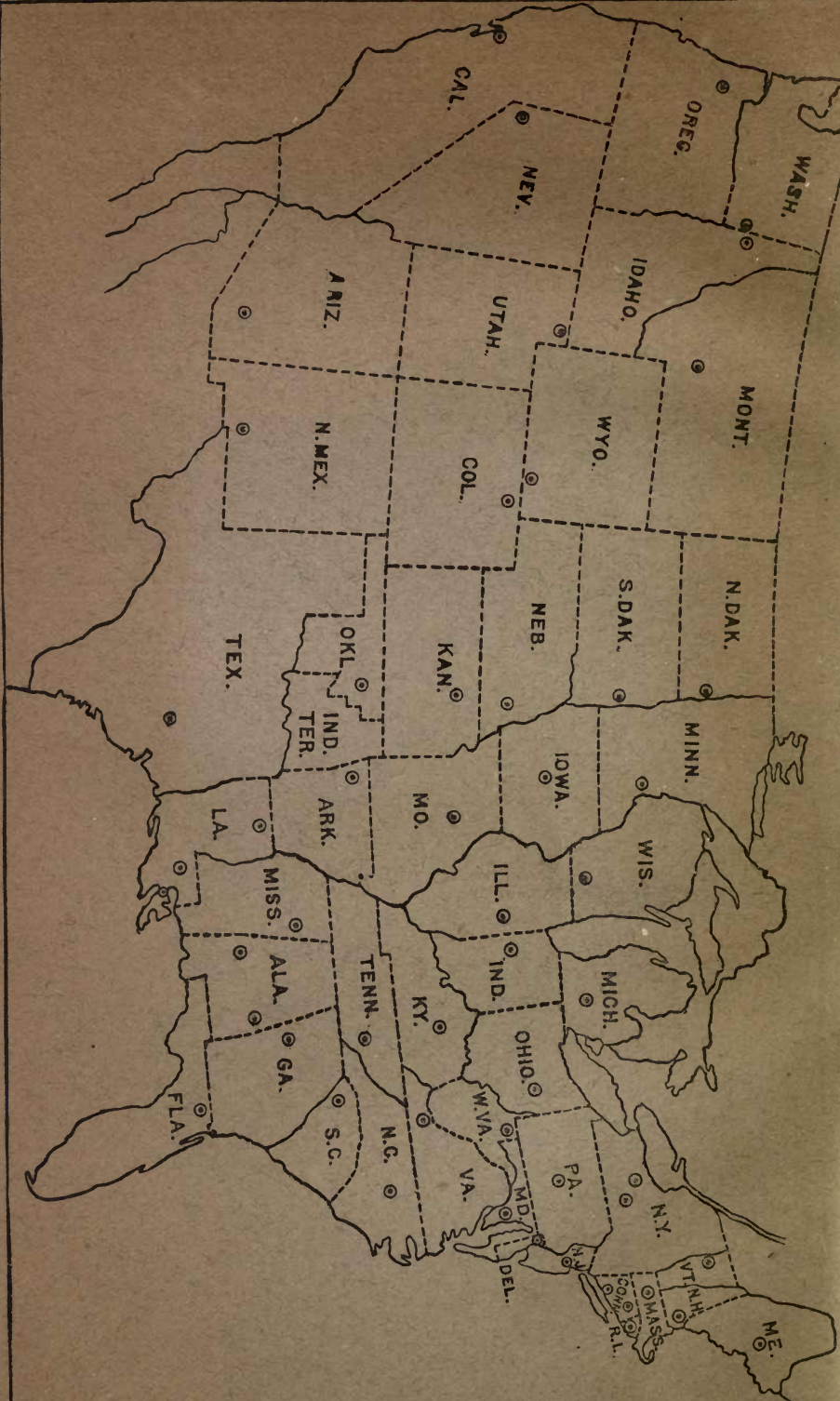
- *Bul. 23. Foods: Nutritive Value and Cost. By W. O. Atwater. Pp. 32.
- Bul. 34. Meats: Composition and Cooking. By C. D. Woods. Pp. 29.
- Bul. 74. Milk as Food. Pp. 39.
- Bul. 85. Fish as Food. By C. F. Langworthy. Pp. 30.
- Bul. 93. Sugar as Food. By Mary H. Abel. Pp. 27.
- Bul. 112. Bread and the Principles of Bread Making. By Helen W. Atwater. Pp. 39.
- Bul. 121. Beans, Peas, and other Legumes as Food. By Mary H. Abel. Pp. 32.
- Bul. 128. Eggs and their Uses as Food. By C. F. Langworthy. Pp. 32.
- Bul. 142. Principles of Nutrition and Nutritive Value of Food. By W. O. Atwater. Pp. 48.
- Bul. 182. Poultry as Food. By Helen Atwater. Pp. 40.

CIRCULAR.

- Cir. 46. The Functions and Uses of Food. By C. F. Langworthy. Pp. 10.

SEPARATES.

- *Food and Diet. By W. O. Atwater. Reprinted from Yearbook of Department of Agriculture for 1894. Pp. 44.
- Some Results of Dietary Studies in the United States. By A. P. Bryant. Reprinted from Yearbook of Department of Agriculture for 1898. Pp. 14.
- Development of the Nutrition Investigations of the Department of Agriculture. By A. C. True and R. D. Milner. Reprinted from Yearbook of Department of Agriculture for 1899. Pp. 16.
- The Value of Potatoes as Food. By C. F. Langworthy. Reprinted from Yearbook of Department of Agriculture for 1900. Pp. 16.
- Dietaries in Public Institutions. By W. O. Atwater. Reprinted from Yearbook of Department of Agriculture for 1891. Pp. 18.
- The Cost of Food as Related to its Nutritive Value. By R. D. Milner. Reprinted from Yearbook of Department of Agriculture for 1902. Pp. 19.
- Scope and Results of the Nutrition Investigations of the Office of Experiment Stations. Reprinted from Annual Report of the Office of Experiment Stations for the year ended June 30, 1901. Pp. 50.
- Dietary Studies of Groups, Especially in Public Institutions. By C. F. Langworthy. Reprinted from Annual Report of the Office of Experiment Stations for the year ended June 30, 1902. Pp. 34.



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